Metamorphic Reactions

Chapter 14B

Univariant Reaction Lines

- The grid define stability limits
  - End-member minerals
  - Mineral assemblages
- More thermodynamic data is needed to construct a useful grid

Isograds

- Mark the intersection of the ground with a Univariant reaction curve
- Example: cordierite reaction to Mg-Fe garnet defines the garnet isograd

Problems with Isograds

- Most rocks have complex compositions, (Mg,Fe) or (Na,Ca) substitutions
- Many reactions are at least divariant
- Even isograds in simple rocks are "smeared"

Coupled Reactions

- Involve several minerals
- Appearance or disappearance of key minerals
  - Depends on rock compositions
- Presence or absence of quartz is a factor

Stability of Muscovite

- With quartz Mus decomposes at a lower T

Muscovite = K-spar + corundum + water

$KAl_2AlSi_3O_{10}(OH)_2 + SiO_2 = KAlSi_3O_8 + Al_2O_3 + H_2O$

- Without quartz Mus decomposes at a higher T

Muscovite + quartz = K-spar + Sillimanite + water

$KAl_2AlSi_3O_{10}(OH)_2 = KAlSi_3O_8 + Al_2SiO_5 + H_2O$

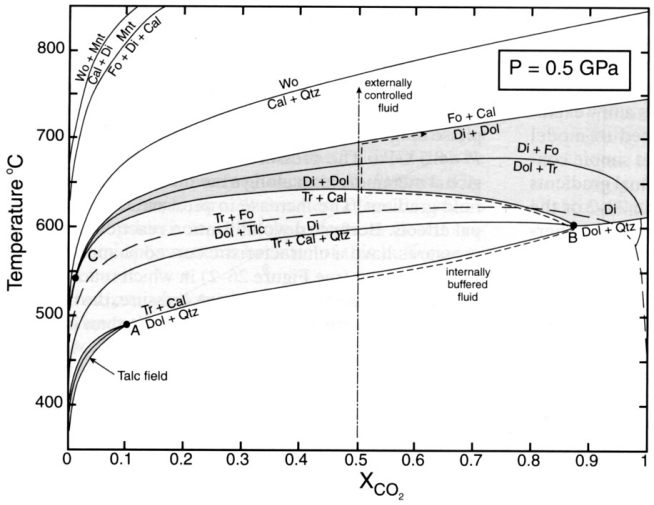
Reactions in Rocks

- **More complicated than in theory**
- **Generally the conditions of metamorphism can be estimated**

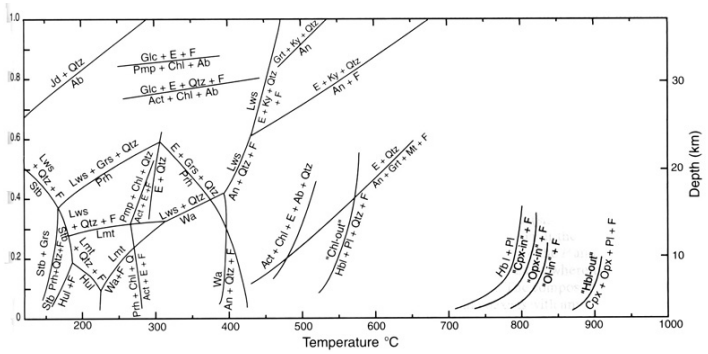
Regional Calc-silicate

Sequence of appearance

- Talc (low X_{CO2})
- Tremolite
- Diopside
- Forsterite
- Wollastonite



Regional Pelitic Rocks



Chlorite Zone

- Lowest Barrovian zone
- Typically slates

Biotite Zone

- Under medium P-T the following reaction occurs at 400-450°

  $Chl + Kfs = Bt + Ms (+ Qtz + H_2O)$

- K-spar is generally consumed before all chlorite is consumed, thus it persists

Chloritoid

- Chloritoid introduction may occur at T > 250º

  Chl + Prl = Cld (+ Qtz + H_2O)
- Chloritoid goes out at T = 590°

  Cld = Grt + St (+Qtz +H_2O)

Garnet Zone

- In Fe-rich rocks at ~ 525°

  Fe-Chl (+ Qtz) = Alm (+ H_2O)
- Under medium P-T in normal pelites the reaction occurs at ~ 610°

  Chl (+Ms + Qtz) = Grt + Bt (+ H_2O)

Staurolite zone

- Under medium P-T may appear at 570°

  Cld + Ky = St + Chl (+Qtz +H_2O)
- An alternate reaction occurs at 610°

  Grt + Chl = St + Bt (+Qtz +H_2O)
- Staurolite goes out at ~700°

  St (+Ms +Qtz) = Grt +Bt +Als +H_2O

Kyanite Zone

- Under medium P-T at ~630°

  St + Chl (+Ms +Qtz) = Ky + Bt (+H_2O)
- This reaction is considered the transition to the granulite facies in pelitic rocks

Sillimanite Zone

- A polymorphic transformation occurs at ~ 690°

  Ky = Sil
- Sillimanite nucleates as tiny needles on micas
- Muscovite goes out at ~ 790°

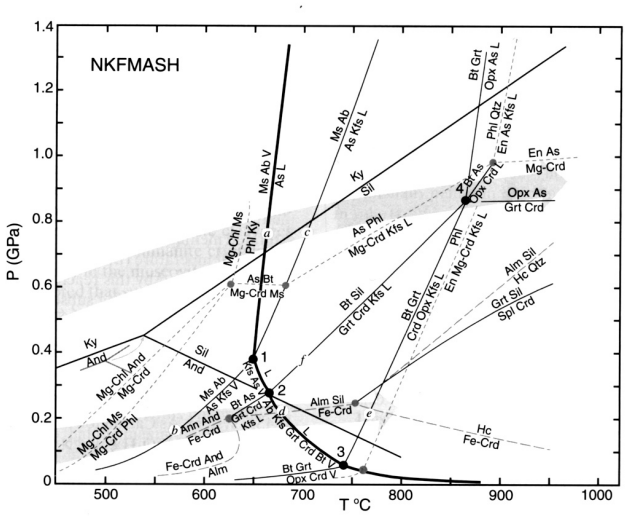
  Ms + Qtz = Kfs + Sil + H_2O
- Cordierite appears at higher temperatures

  Phl + Sil (+Qtz) = Mg-Cdr (+Kfs + H_2O)

Melting of Pelites

- Assume all the water is due to metamorphic dehydration reactions
- Muscovite decomposition causes melting, provided the pressure is high enough to retain the water

  Ms + Ab + Qtz = Al_2SiO_5 + Kfs + L



Migmatites

- Dehydrated rocks become granulites
- Some high-grade rocks appear "mixed"
  - Dark schistose layers (melanosome) alternate with
  - Light-colored igneous-looking layers (leucosome)
- The leucosome has a tonalite composition
  - Not that of a minimum melt
- They represent high-grade metamorphic rocks in which melting is important

Metasomatism Model

- **Obvious in rocks with contrasting mineral layers**
- **Related to unequal partitioning of elements between solid phases and fluids**
- **Model uses ion-exchange reactions**

Potassium Migration

- **K^+ is concentrated relative to Na^+ in chloride fluids**
- **In fractured rock under a T gradient K^+ moves toward higher temperature regions**
- **K-spar is replaced by Na-spar in low temperature regions**
- **This could explain large K-spar megacrysts**

Amphibolite Facies Metasomatism

- **Alternating sedimentary layers with more and less calcite**
- **Leads to slightly different plagioclase composition in metamorphic bands**
- **Ion exchange produces plagioclase and K-spar bands**